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RADAR SURVEILLANCE IN SUPPORT OF 1983 COAATF OIL SPILL TRIALS

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RADAR SURVEILLANCE IN SUPPORT OF 1983 COAATF OIL SPILL TRIALS

by

Intera Technologies Ltd.
Calgary, Alberta

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April, 1984

RADAR SURVEILLANCE IN SUPPORT OF 1983 COAATF OIL SPILL TRIALS

prepared for
ENVIRONMENTAL PROTECTION SERVICE
DSS CONTRACT #KE145-3-0412

SCIENTIFIC AUTHORITY M. FINGAS

prepared by
INTERA TECHNOLOGIES LTD.
Calgary, Alberta

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David F. Grant

EXECUTIVE SUMMARY

In this program 15 oil spills were detected utilizing INTERA's SLAR radar system. A preliminary oil spill trajectory evaluation shows that these spills tended to move west or southwest at approximately 0.6-1.3 km/hr. The dominant factor in this oil spill movement appears to be the "mean" alongshore current that moves relatively freshwater from the outflow of the St. Lawrence river down the Nova Scota coastline.

Over this 7 day program 12 flights were completed; accumulating 20 hours of flight time. The average flight covered approximately 16000 km^2 in 1.7 hours (total flight time). The map like radar imagery provided reliable near real-time information on spill number, size, location and movement. The juxtaposition of the Edward Cornwallis, the Shoreham, the sampling vessels, fishing buoys, passing vessels and landfall is indicative of the detailed information that can be provided utilizing airborne radar imagery.

The all weather operation, wide aerial coverage and low capital and operating costs of a modern lightweight digital radar system provides the most cost effective technique of obtaining the vital stragetic and tactical information required to detect and combat oil spills in the open ocean.

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1. INTRODUCTION

This report has been prepared to summarize the radar surveillance program undertaken to support the September 1983 COAATF Oil Spill Trials.

Emphasis in this study was placed on: 1) a technical description of the SLAR system; 2) a summary of the SLAR flight program and data collected; 3) an evaluation of the position and possible trajectory of each oil spill, 4) a preliminary evaluation of INTERA's lightweight digital SLAR for oil spill detection, 5) further evaluation of the oil spill data set.

The fiscal limitation imposed on the report by increasing the number of flight hours beyond those originally contracted has prevented a detailed evaluation of the oil spill detection capability of the radar for various environmental and radar parameters.

2. SLAR SYSTEM TECHNICAL DESCRIPTION

This section describes the radar and aircraft systems utilized for 1983 COAATF Oil Spill Trials. Although not utilized in this program a brief description of the real time downlink system is also provided.

2.1 MAPR RADAR SYSTEM

INTERA's MAPR (Marine Airborne Patrol Radar) SLAR system configuration is shown in Figure 2.1. The antennae are back-to-back horns, 12 ft. long and 6 in. deep, fed from slotted waveguide runs. The antennae are hard-mounted to the aircraft belly. The antenna gain is 34 dB or better, and the azimuth beam width is 0.57° at the 3 dB points. Side lobes in azimuth are depressed 24 dB below the main lobe. The antenna depression angle is set to achieve optimum illumination over two swaths of 50 km on each side of the aircraft, excluding a "dead" spot below the aircraft that is equal in width to three times the aircraft altitude. The antennae transmit and receive in horizontal polarization.

The transceiver contains a magnetron-type transmitter tuned to 9.375 GHz (X-band), which transmits a 250 nsec pulse at 20 KW peak power with a PRF scaled to the ground speed. At 300 knots ground speed, the PRF is 1536 Hz. The receiver has either a linear or a logarithmic response, and has a low noise figure of 3 dB. The transmitter is switched from the left to the right antenna every 256 transmitter cycles, allowing simultaneous imaging to the right and left of the aircraft track.

The signal processor and display formatter digitize the video stream and, using a 4 MBit video memory, provide various signal processing functions. One of a total of 32 different, programmable STC functions can be applied to each received line; received lines are averaged and formatted for the TV display.

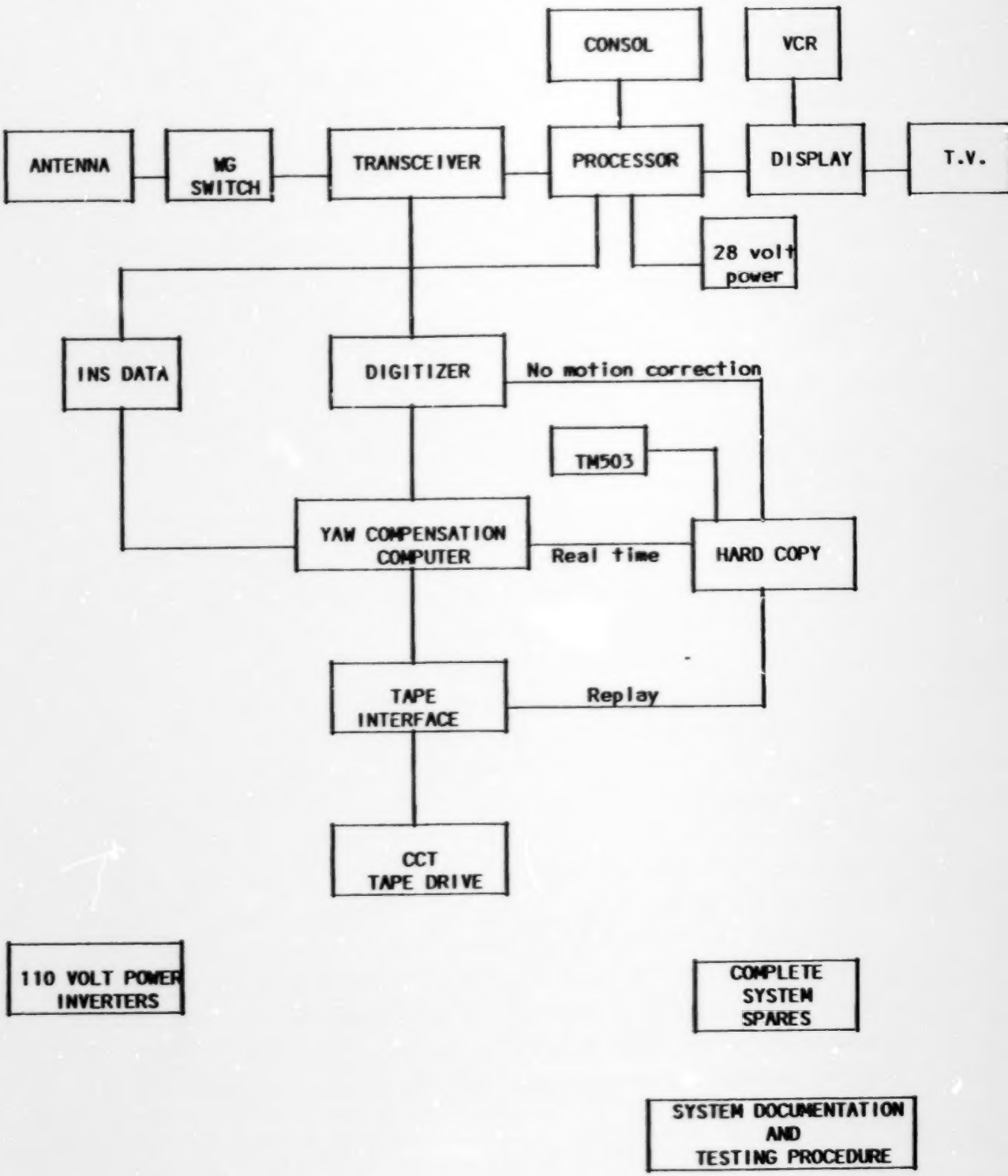


Figure 2.1 MAPR SLAR configuration.

Using the control console, a 20, 40 or 80 km swath width from either or both sides of the aircraft can be displayed on the high resolution, North American Standard TV display, or the image can be "zoomed". Housekeeping data, such as present position and ground speed, can be displayed on the screen. The video cassette recorder (VCR) retains all displayed data for later analysis.

The digitizer or SLAR interface receives the video stream from the signal processor and prepares it for hard-copy display and digital recording. The intensity information is digitized to 4 bits and the "dead spot" between left and right images is eliminated. The output of the SLAR interface is a series of digital image lines, each 2048 cells long, representing total swath widths of 50, 100 or 200 km.

The motion compensation computer receives heading information from the navigation system which allows for the correction of yaw induced geometrical errors. System design provides for yaw angle correction of $\pm$ 20° with a yaw angle resolution of 0.2°.

The hard-copy device utilized in the ice surveillance system is the SORO Visor S. This display is capable of reproducing the required 2000 range resolution cells, on either heat-processed, dry silver film or heat-processed, dry silver paper.

Reformatted, motion compensated imagery from the tape interface is recorded digitally on the Pertec Recorder. Playback is normally at a speed of five times that at which the data are recorded.

A digital downlink system is available for operation with the MAPR SLAR. This downlink consists of a formatter which prepares the video stream (after motion compensation), for transmission, and a VHF transmitter operating at 219.5 MHz. The receive station includes a receiver, deformatting bit synchronizer, tape controller and a Kennedy 9100 tape drive. An Edo Western 590 display, which produces a 9 inch (20 cm) format negative or positive film transparency, or a heat processed dry silver paper product is included. The range of the downlink is about 360 km (190 nm). when the aircraft is operated at 33 000 ft. altitude.

2.1.1 System Performance

The performance characteristics of the MAPR SLAR system are summarized in Table 2.1. This system has demonstrated its ability to map sea ice, oil spills, icebergs and various terrain and cultural targets. For the oil spill application the system is operated in the 25 km/side mode at an altitude of 5000 ft. To maximize the radar return from the sea surface, minimum range delays (thus steepest depression angles) are utilized. System gain is adjusted until the return in the near range begins to saturate.

The mechanism by which an oil spill is identified on a radar image depends on the dampening of the capillary waves within the polluted area. This smoothing of the sea surface provides a lower return of the transmitted EM pulse (relative to the background sea clutter) to the radar receiver producing a darker area on the positive radar imagery. Experience has shown that sea clutter is greatest for the upwind look direction improving the "contrast" between oil and unpolluted ocean water. Figures 2.2 and 2.3 are examples of radar imagery collected during this program. Illustrated are the test and control spills, the merged test and control spills, the Cornwallis and various sampling vessels.

2.1.2 Navigation Systems

The navigation system on the aircraft includes interfaces between the primary navigation data source, an LTN-76 inertial navigation system, and the SLAR, autopilot and flight control system. This integrated navigation system is necessary to ensure that the programmed flight lines are flown to within the most exacting tolerances. The INS itself is normally accurate to within its drift rate which, for this platform, is about 1 nmi per hour. The INS can correct for this drift automatically when operated as an "area navigation" system. In this mode the INS continuously receives two DME or one VOR and one DME signal, which it uses to compute the aircraft position to an absolute accuracy of about 250 m. The true ground speed is updated with the same system to an accuracy of about 0.1%. This level of accuracy is desirable because actual ground speed is required to drive the radar PRF and thus the along track scale factor. The programmed flight line is then flown by the autopilot

Table 2.1 MAPR SLAR performance specifications.

Wavelength	3 cm
Polarization	HH
Tx Power	20 kw peak
Range Resolution	40 m
Azimuth Resolution	9 m/km
Swath Width (TV)	20, 40, 80 km each side
Swath Width (Hard-Copy)	25 km/50 km/100 km each side
Minimum Detectable Reflectivity at 55 km range with 5 dB S/N	-40 dB
Total System Weight	600 lbs. (272 kg)
Total System Power Required	12 Amp 120 Volt 60 H_z 12 Amp 28 Volt

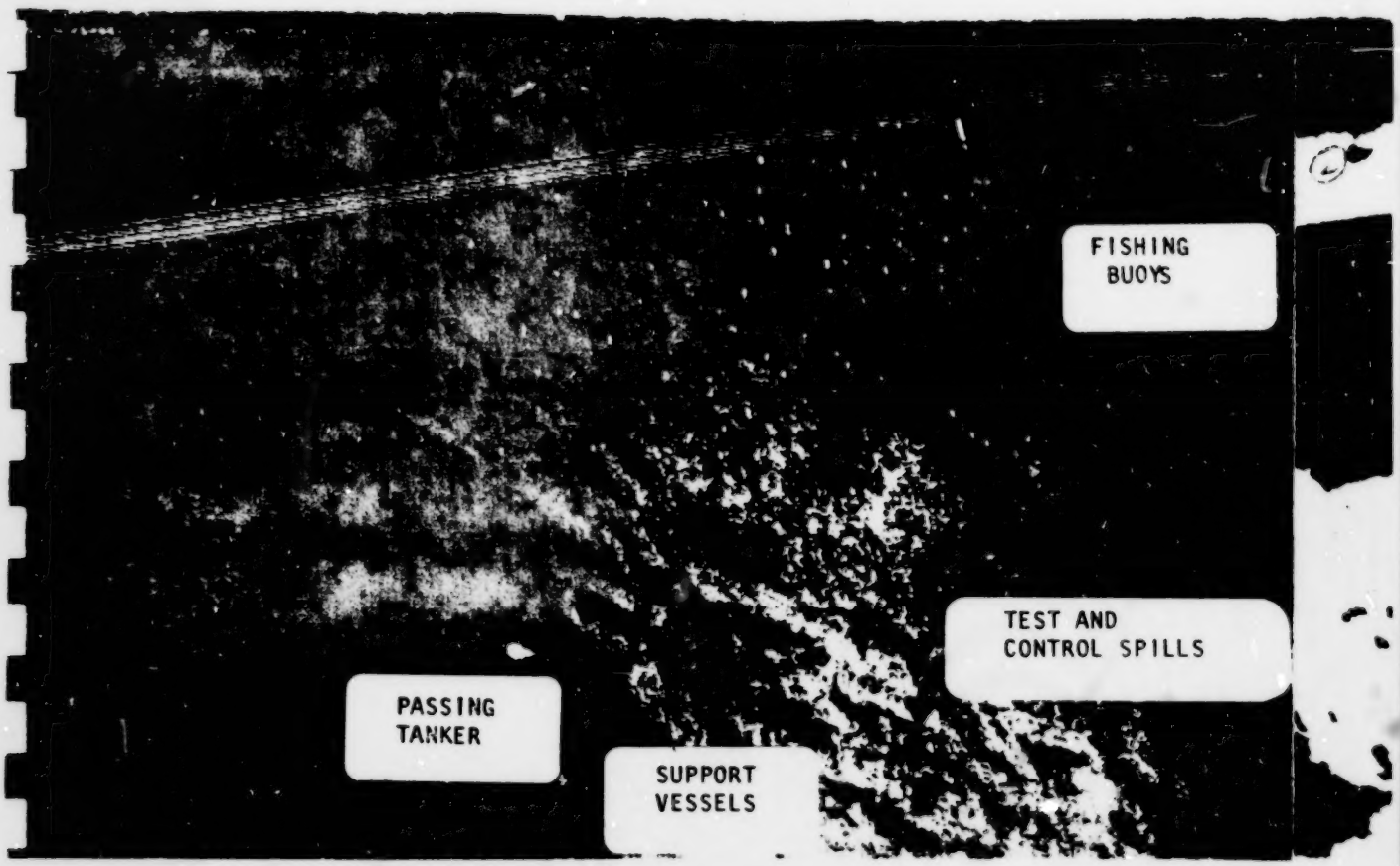


Figure 2.2 Test & control spills, support vessels & passing tanker.
12 September 1983 1600 hr.

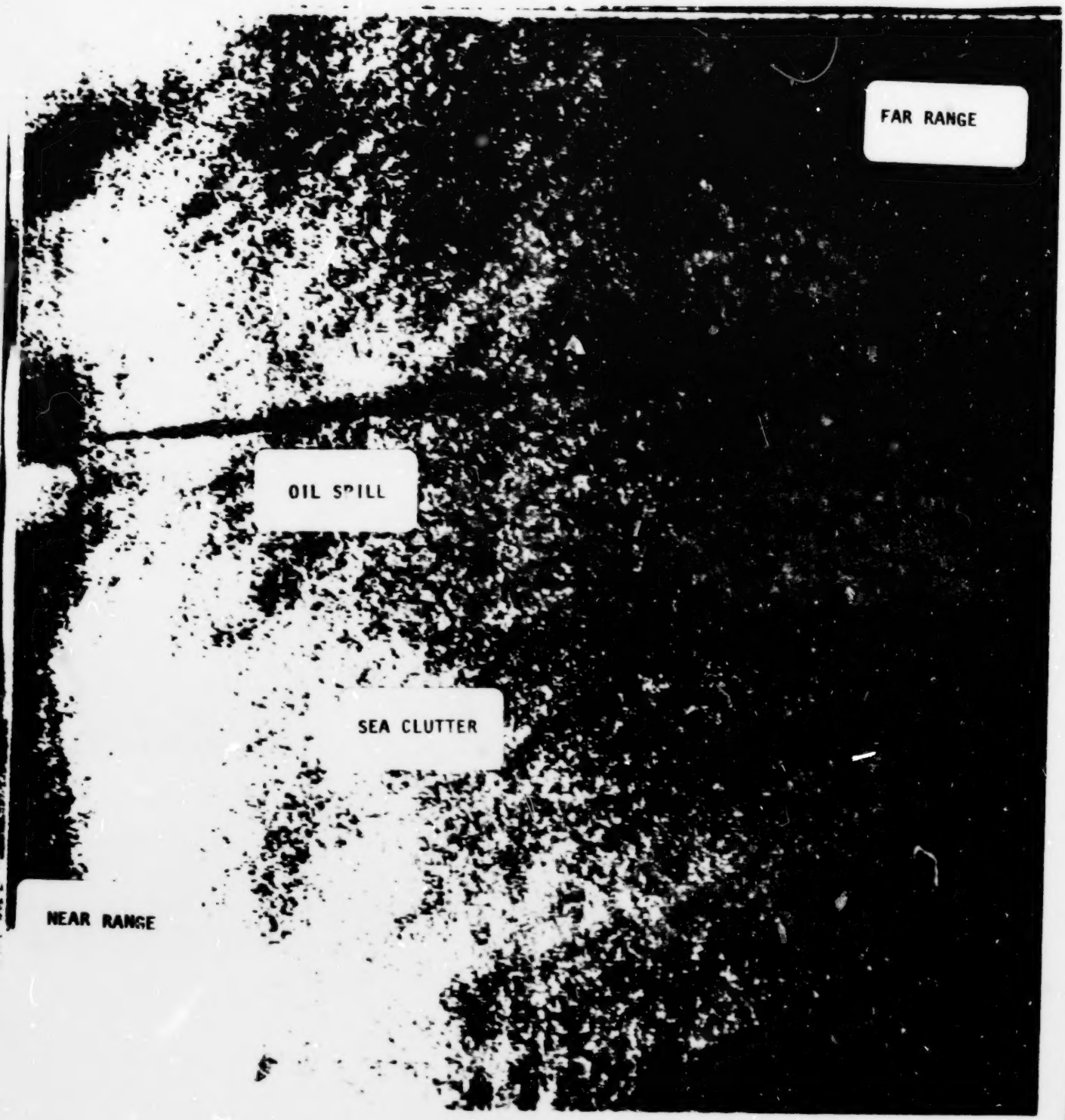


Figure 2.3 1:125,000 scale enlargement of 8 km long spill
17 September 1983 1800 hr.

without "hands-on" control by the pilots. At the same time, the digital motion compensation system utilizes the INS data to correct the radar data for aircraft yaw.

2.1.3 Aircraft Description

The MAPR SLAR system is mounted on a Cessna Conquest, a twin-engine, turboprop, pressurized aircraft with a gross weight of 10800 lbs. The size of this aircraft, which has an 11-passenger capacity, has permitted the installation of a custom-tailored instrumentation package for aerial surveillance. Figure 2.4 illustrates the MAPR aircraft and antennae.

Performance characteristics of the Conquest are listed in Table 2.2. A typical mission of five-hour duration would cover approximately 1250 NM.

The selection of the Conquest to serve as the operating platform for the aerial surveillance package was made subsequent to a comparison of the performance capabilities, the operational cost and the performance reserve for crew safety.

The payload is estimated as follows:

Equipment:	
SLAR	
Power supplies	
Recording & Display Systems	664 lbs
Crew:	
Pilot	
Technician	340 lbs.
Supplies:	
Safety equipment	
Spares	
Test equipment	
Tape and film	190 lbs.
TOTAL PAYLOAD	1194 lbs.

Figure 2.4 MAPR SLAR aircraft and antenna.

Table 2.2 Cessna Conquest performance data.

Maximum Take-Off Gross Weight	10800 lbs.
Minimum Take-Off Runway Length, SL., Std. at max. T.O. Wt.:	2600 ft.
Maximum Cruise Speed at 30 000 ft.	290 kt.
Maximum Fuel Capacity:	3200 lbs.
Average Fuel Flow at 30 000 ft.	420 lbs./hr.
Maximum Endurance in Surveillance Configuration	7.0 hr.
Normal Endurance in Surveillance Configuration	5.0 hr.
Time to Climb to 30 000 ft. (max. gross)	24 min.

The performance requirements placed on this aircraft for various aerial surveillance missions are easily met at operating weights up to maximum gross weight. The aircraft has full airline standard de-ice on props, wing and windshield. Furthermore, this aircraft has a substantial performance reserve for operations in known icing conditions.

The interior of the aircraft permits a workable layout for the instrumentation. Electrical power requirements are met with the standard aircraft power sources. Main DC electrical power is provided by two 300 amp, 28 volt, 400 Hz inverters and six 110 volt, 60 Hz inverters. A systems power distribution panel serves to isolate the aircraft electrical load requirements from those of the instrumentation. The air conditioning system provides in-flight cabin pressurization, heating, cooling and ventilation. Cabin pressurization can provide a pressure differential up to 6.3 p.s.i; this provides a 10 000 ft. cabin at 33 000 feet.

The aircraft is equipped with a complete IFR avionics package. The avionics package includes dual VOR-DME receivers, and an integrated VLF and flight director system coupled to the autopilot. The L-band ATC transponder has a 4096 code capability, complete with altitude reporting. A digital display weather radar is mounted in view of both the pilot and co-pilot. The radar has selectable range displays, from 160 to 5 nm full-scale display.

The communications system on the Conquest includes dual 720 channel VHF transceivers, an HF radio for long-range communication and an intercom network. Four crew stations are interfaced to the intercom and transceiver systems to permit monitoring any combination of the radios.

Normal flight crew for the Conquest requires only a pilot, and an engineer. On this program two mission managers were available to provide liaison with the client, to facilitate the timely reduction of the incoming data, to plan the forthcoming missions and to prepare for evening and morning briefings.

2.1.4 Safety Equipment

The Conquest is equipped with the following safety equipment for operation in the offshore areas of the world:

1. Four-man life raft complete with emergency locator transmitter;
2. Sea wolf immersion suits;
3. Four-man survival kit complete with flares;
4. Emergency escape hatch over starboard wing; and
5. Winter parkas, mits and boots.

3. SUMMARY OF SLAR FLIGHTS

3.1 SLAR FLIGHTS

Table 3.1 summarizes the 12 flights undertaken in support of the 1983 COAATF Oil Spill Trials. For comparative purposes a description of the surface environmental conditions (see APPENDIX B for details) and a brief desciption of the oil spills observed during each flight is provided. The average mission flown covered approximately 16,000 km^2 and required 1.7 hours of total flight time. A 4.5 hour mission would have provided coverage of approximately 45,000 km^2.

Figure 3.1 illustrates an example of a mission plan to provide a detailed search that will cover 22,000 km^2. This mission would require approximately 2.3 hours total flight time.

3.2 DATA ARCHIVE

During this program the data were collected and permanently archived in several formats:

1. real time dry silver paper;
2. digital CCT;
3. VCR (1/2" & 3/4")
4. radar log sheets

The CCT data and 1/2 VCR data are available for all periods in which the radar was utilized. During this program 3/4 inch VCR data was collected on a trial basis to evaluate the benefits of the extra bandwidth available with the 3/4 inch format. Due to the temporal limitations of the 3/4 inch tape these data were generally collected over those areas in which an oil spill had been positively identified.

The real time dry silver paper and log sheets are contained under separate cover as APPENDIX A. Indexes of the CCT's and VCR data are contained in APPENDIX C. The VCR's and CCT's are currently stored in INTERA's Calgary office.

Table 3.1. Summary of SLAR Flights 1983 Oil Spill Program.

FLIGHT NO.	DATE	TIME		TYPE OF FLIGHT	WIND		SEA STATE		RADAR PARAMETERS		REMARKS
		TAKE OFF LOCAL	DURATION (HRS)		MAG (KN)	DIRECT.	WAVE HEIGHT (M)	DIRECT.	SWATH WIDTH (KM)	ALTITUDE (FT)	
1	12 Sept.	1445	2.25	Map test & control spills	10	SW SW	.4-1.0	SW	50 (25/ side	10,000	Both test & control identified 4.4 km NE of spill site (spills 1.2 km apart). Test spill released first and is generally bigger than control spill.
2	13 Sept.	0800	1.83	Search for 12 Sept.	5	SW	.4	SW	50	5,000	Centroid of spill #1 23.5 km SE of site. Spill poorly defined but appears to be one of the largest observed during trails. Winds 5-10 knots from SW from 1400 12 Sept. to 0800 13 Sept. Sea state, .4-.8m from SW over same period. Spill is likely too large and moving in wrong direction to be related to test and control spills of 12 Sept.
3	13 Sept.	2030	1.88	Night search flight	10-15	NE	N/A	N/A	50	3,000	Large spill 11 km by 1-2 km 21 km west of site. Spill likely result of tanker bilge washing.

Table 3.1. Continued.

FLIGHT NO.	DATE	TIME		TYPE OF FLIGHT	WIND		SEA STATE		RADAR PARAMETERS		REMARKS
		TAKE OFF LOCAL	DURATION (HRS)		MAG (KN)	DIRECT.	WAVE HEIGHT (M)	DIRECT.	SWATH WIDTH (KM)	ALTITUDE (FT)	
4	14 Sept.	0800	1.88	Search for spills of Sept 12/13	15	NNE	.8	NE	50	3,000 to 5,000	Spill 2.0 km long by .25-50 km wide. Winds NE at 15 km since 2000 13 Sept. sea state also from NE. Wind, sea state and alongshore (SW moving) could have moved spill #2 to this location. Movement 11.5 km/.2 hr = 1 km/hr. 1 km/hr appears to be a typical oil spill velocity as observed during this program.
5	14 Sept.	2000	1.90	Night search flight	10-15	NE	N/A	N/A	50	5,000	No spills observed.
6	16 Sept.	1200	2.00	Map test & control spills	10-15	NW	.4	N/NW	50	5,000	Both test & control identified. Test 1.5 times as long as control. Spills laid down with wind and have maintained NW/SE orientation
7	16 Sept.	1900	1.33	Night search flight	12	NW	1.8	N/NE	50	5,000	It appears that test & control spills of 16 Sept. 1200 have combined & spread out to form one large spill Spill #4). Spill #4 is 4.8 km long and 1.3 km wide. Drift 7.5 km in 6 1/2 hours or 1.1 km/hr. Winds NW at 10 knots from 1200 to 1900. Sea state variable from NW to E with a E/SE swell.

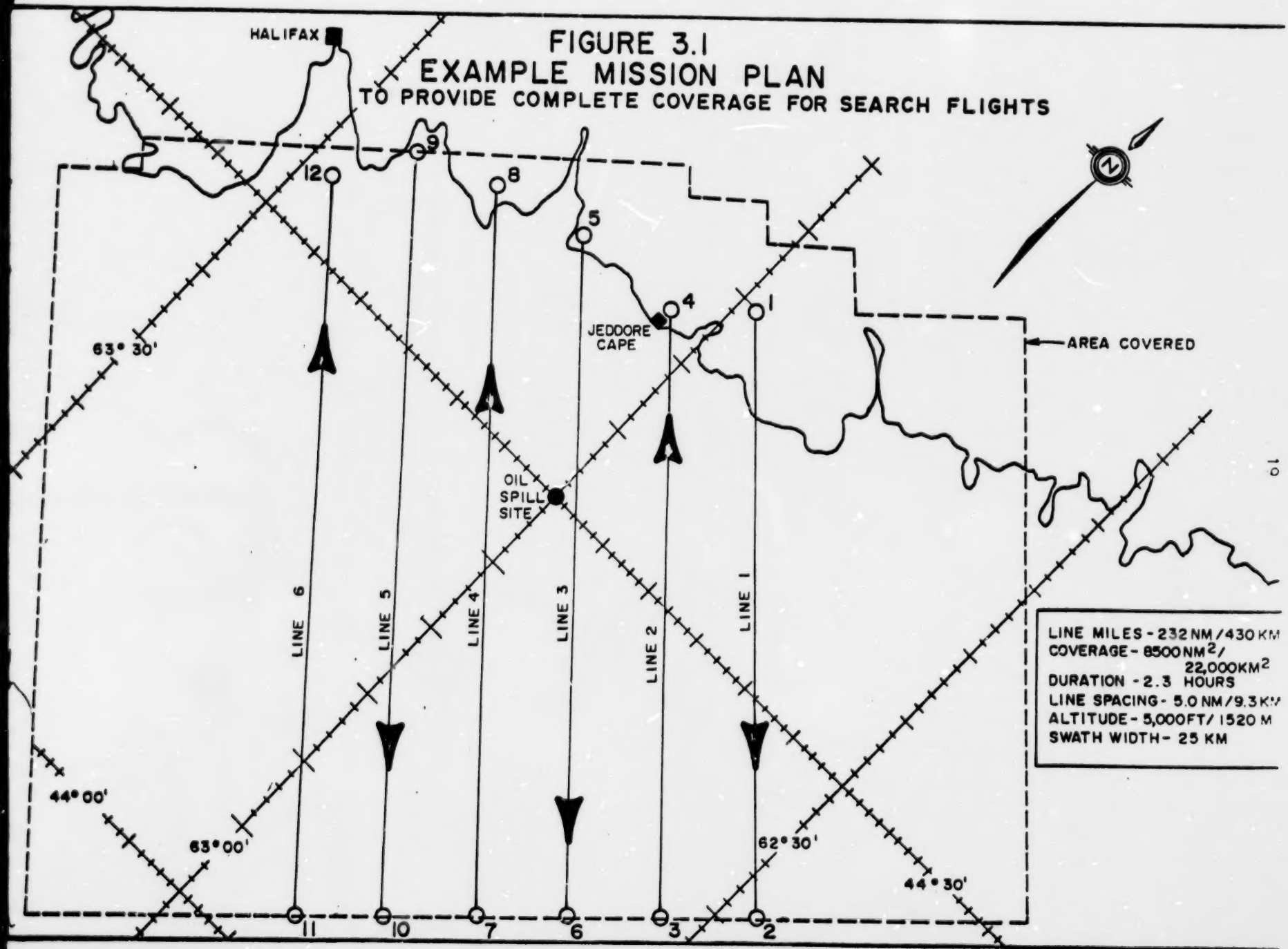
Table 3.1. Continued.

FLIGHT NO.	DATE	TIME		TYPE OF FLIGHT	WIND		SEA STATE		RADAR PARAMETERS		REMARKS
		TAKE OFF LOCAL	DURATION (HRS)		MAG (KN)	DIRECT.	WAVE HEIGHT (M)	DIRECT.	SWATH WIDTH (KM)	ALTITUDE (FT)	
8	17 Sept.	0800	1.58	Search for all spills of 16 Sept.	10	SE	.4	E	50 (TOTAL)	5,000	Spill #5 8 km by 4 km wide observed due west of site of spill #4 of 16 Sept. (1900 hr). Drift 13.5 km/ 13 hr. = 1.0 km/hr. Wind from 1900 16 Sept. to 0800 17 Sept. from each at 10 km. Sea state also from east.
9	17 Sept.	1200	1.18	Map test & control spills	8-10	SE	1.0 - 1.2	SE	50	5,000	Both test & control spills observed. Test larger. Spills laid down with wind. Also observed 3 km by 1 km spill (spill #6) Winds from SE at 8-10 knots. Sea state .4 to 1.2 m from east.
10	17 Sept.	1800	1.18	Night search flight	15	SE	1.2	SE	50	5,000	Winds from 1200-1800 17 Sept. SE at 15 knots. Sea state 1.2 m. Test & control spills have merged to form a slick (spill #7) 6 km long by .6 km wide. Drift 9.8 km over 6 hours or 1.63 km/hr. Also spill SE of Halifax Harbor (spill #8).

Table 3.1. Continued.

FLIGHT NO.	DATE	TIME		TYPE OF FLIGHT	WIND		SEA STATE		RADAR PARAMETERS		REMARKS
		TAKE OFF LOCAL	DURATION (HRS)		MAG (KN)	DIRECT.	WAVE HEIGHT (M)	DIRECT.	SWATH WIDTH (KM)	ALTITUDE (FT)	
11	18 Sept.	1200	1.5	Search for spills of 16/17 Sept.	10-15	NW	N/A	N/A	50	5,000	No oil observed.
12	18 Sept.	1330	1.33	Search for spills of 16/17 Sept.	N/A	N/A	N/A	N/A	50	5,000	Oil observed on beach at Jeddore Cape 20 km north of spill site.
SUMMARY		20 HRS	1.67								12 flights were flown in 7 days. Three were directly to support oil spills; 5 daylight search flights & 4 night search flights were also conducted. 15 observations of oil spills were made.

FIGURE 3.1
EXAMPLE MISSION PLAN
TO PROVIDE COMPLETE COVERAGE FOR SEARCH FLIGHTS



4. OIL SPILL TRAJECTORY EVALUATION

4.1 CALCULATION OF OIL SPILL TRAJECTORIES

Throughout each flight the radar operator and mission manager studied the T.V. display and hard copy imagery for evidence of an oil spill. The position of suspected targets was noted and on subsequent flightlines the same area was carefully reviewed for further evidence of oil on the surface. Where possible, visual verification of the oil spill was obtained from the pilot.

The position of each "verified" target was calculated utilizing a software program available to INTERA. Input to the program includes the latitude and longitude information from the INS, the viewing geometry of the radar and the physical dimensions of the output imagery. Utilizing this software the position of any target in the radar image can be calculated. This software is currently provided on the HP-67 and HP-15 hand held calculator making real time calculations in the aircraft possible. Output from the program includes:

- heading between waypoints on each line;
- cross track scale factor;
- along track scale factor;
- latitude/longitude of target;
- distance and bearing of target 1 to 2.

Table 4.1. summarizes the calculation of the position all targets identified during this program (Table 4.1 is provided in APPENDIX D). To define the outline of an oil spill often 3 or 4 positions along the perimeter of the oil spill were calculated. To facilitate the evaluation of possible oil spill trajectories all spills that could be related to the test and control spills of September 12 are plotted on figure 4.1. Figures 4.2 and 4.3 summarize the oil spills that could be related to the test and control spills of September 16 and 17.

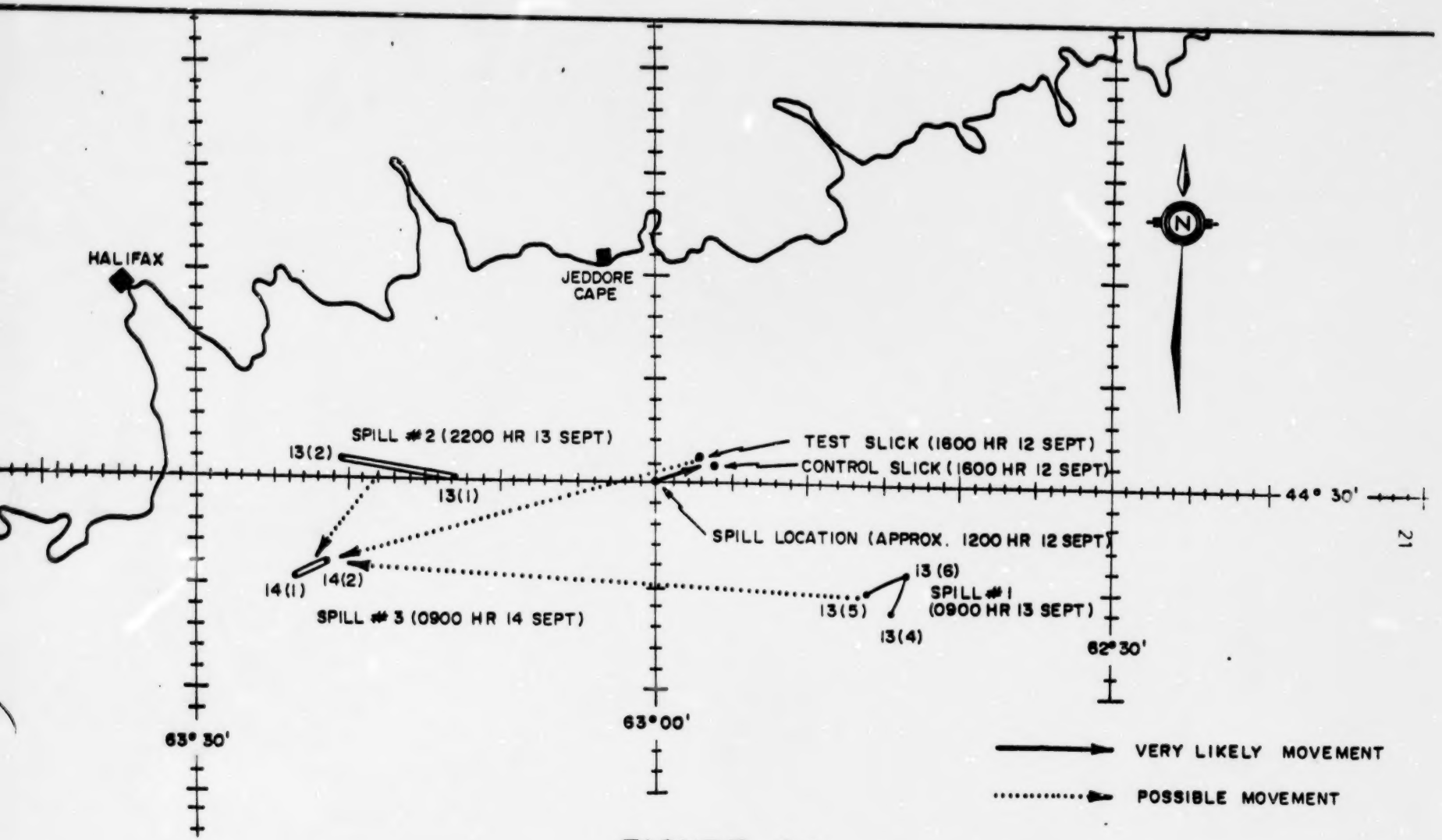


FIGURE 4.1
OIL SPILL LOCATION
12 SEPTEMBER OIL SPILL

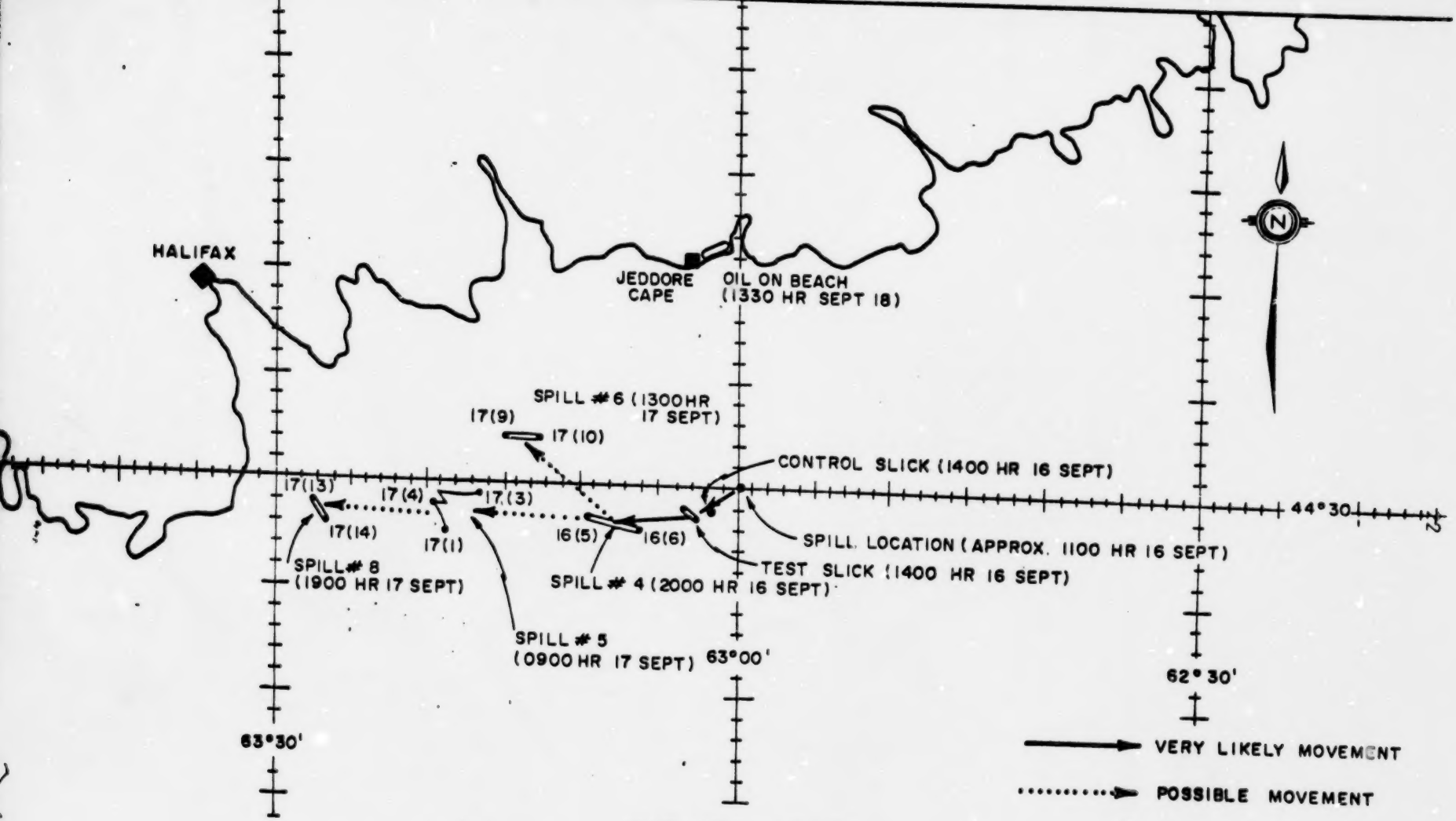


FIGURE 4.2
OIL SPILL LOCATION
16 SEPTEMBER OIL SPILL

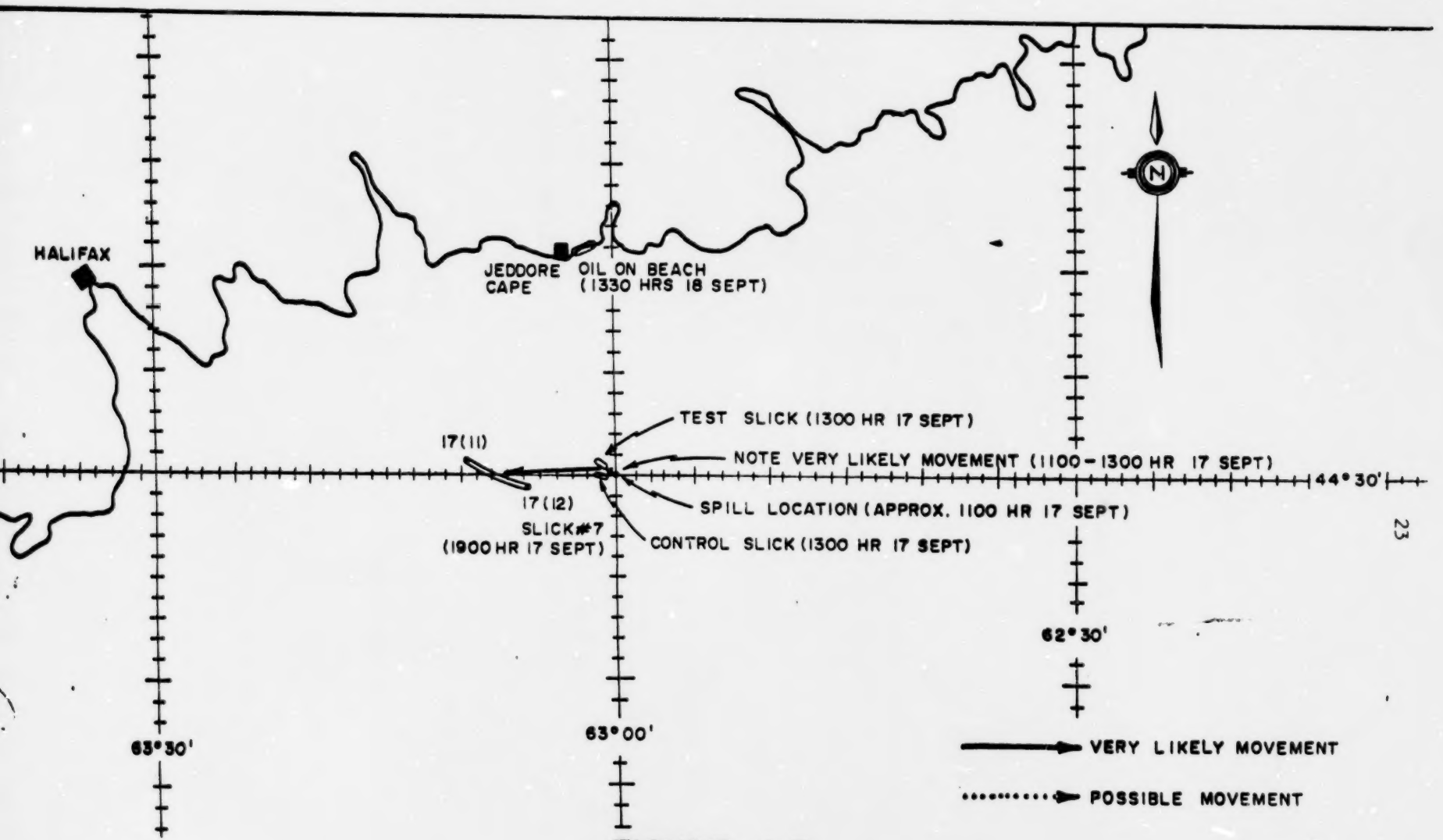


FIGURE 4.3
OIL SPILL LOCATION
17 SEPTEMBER OIL SPILL

Table 4.2. summarizes the possible trajectories that have been tested against the following criteria:

- prevailing wind direction between observations;
- alongshore current direction;
- oil spill drift velocity.

Trajectories moving against the "mean" alongshore current and prevailing wind direction were considered unlikely. Trajectories moving at velocities in excess of 2 km/hr were also considered unlikely. Movements satisfying the directional and drift rate criteria were subdivided into either very likely movements or possible movements.

The superposition, of several spills of 'unidentified origin', in the experiment area made long term tracking of the spills difficult. The most consistent and verifible information on oil spill trajectory was obtained over the period 2-10 hours from the dumping of the test and control slicks. The results of the trajectory evaluation are plotted on figures 4.1, 4.2 and 4.3.

4.2 CONCLUSIONS OF OIL SPILL TRAJECTORY EVALUATION

4.2.1 Oil Spill 12 September 1983

Assuming that the original test and control slicks were dumped at 44°30'N 63°00'W the identification of both spills at 1600 hr indicates that they were drifting to the NE at 1.3 km/hr. This movement was against the "mean" alongshore current but with the prevailing wind direction. This is the only movement classified as "very likely" that moved against the alongshore current. During the morning flight of September 13 (0900) the only spill identified was found at position #1 of figure 4.1. Prevailing wind speed and direction suggest that the test and control spills of 12 September are not related to this spill. The heavy rains evidenced on the imagery of the morning of 13 September may have acted as a natural dispersant preventing the detection of the test and control slick(s).

Table 4.2. Trajectory summary. Oil Spill Trials September 1983.

OIL SPILL	TEST TRAJECTORY	OBSERVATION$_1$		OBSERVATION$_2$		WIND BETWEEN OBSERVATIONS		SEA STATE BETWEEN OBS.		DIST. MOVED (KM)	TIME ELASPED (HR)	VELOCITY (KM/HR)	DIR OF DRIFT	REMARKS
		DATE	APPROX. TIME	DATE	APPROX. TIME	SPEED (KM)	DIR (FROM)	HT (m)	DIR (FROM)					
OIL SPILL 12 SEPTEMBER	spill location to Test & Control (1600 hr)	12 Sept.	1200	12 Sept.	1600	10-15	SW	1.0 - 1.5	SW	5.4	4.0	1.34	NE	- observation #1 assumes oil spill at 4430N & 6300W. - trajectory classed as very likely - movement against alongshore current but with wind direction.
	T&C(1600) to Position 1	12 Sept.	1600	13 Sept.	0900	5-10	SW	.4 - .8	SW	19.8	17.0	1.16	SE	- movement against wind & sea direction - trajectory classed as unlikely
	T&C to Position 2	12 Sept.	1600	13 Sept.	2200	5-10	SW	.4 - .8	SW	28.9	30.0	1.96	W	- movement against wind & sea direction but with alongshore current - size & shape of spill suggest origin tanker bilge washing - trajectory classed as unlikely
	Position 1 to Position 2	13 Sept.	0900	13 Sept.	2200	5-10	SW switch to NE	.3 - .4	SW switch to NE	45.9	13.0	3.53	NW	- movement with alongshore current & winds & sea of later portion of test period - magnitude very high - trajectory classified as unlikely
	Position 2 to Position 3	13 Sept.	2200	14 Sept.	0900	15	NE	.4 - .8	NE	11.3	11.0	1.03	SW	- movement with along shore currents wind & sea of period. - size considerably smaller but have rain over period - classified as possible movement

Table 4.2. Continued.

OIL SPILL	TEST TRAJECTORY	OBSERVATION$_1$		OBSERVATION$_2$		WIND BETWEEN OBSERVATIONS		SEA STATE BETWEEN OBS.		DIST. MOVED (KM)	TIME ELASPED (HR)	VELOCITY (KM/HR)	DIR OF DRIFT	REMARKS
		DATE	APPROX. TIME	DATE	APPROX. TIME	SPEED (KM)	DIR (FROM)	HT (m)	DIR (FROM)					
OIL SPILL 2	Position 1 to Position 3	13 Sept.	0900	14 Sept.	0900	5-15	SW becomes NE	.4 - .8	SW becomes NE	19.4	24.0	.81	W	- movement with along current wind & sea - magnitude Ok - possible movement
	T&C(1600) to 3	12 Sept.	1600	14 Sept.	0900	10-15	SW/NE	.3 - .8	SW becomes NE	37.0	41.0	.90	SW	- movement with alongshore current & initial winds, velocity OK - trajectory possible

Table 4.2. Continued.

OIL SPILL	TEST TRAJECT-ORIES	OBSERVATION$_1$		OBSERVATION$_2$		WIND BETWEEN OBSERVATIONS		SEA STATE BETWEEN OBS.		DIST. MOVED (KM)	TIME ELASPED (HR)	VELOCITY (KM/HR)	DIR OF DRIFT	REMARKS
		DATE	APPROX. TIME	DATE	APPROX. TIME	SPEED (KM)	DIR (FROM)	HT (m)	DIR (FROM)					
OIL SPILL 16 SEPTEMBER	Spill location to T&C location	16 Sept.	1100	16 Sept.	1400	15	NW	.3-.4	N/NW	3.9	3	1.3	SW	- movement with alongshore current and wind direction & - trajectory classified as very likely
	T&C to POSITION 4	16 Sept.	1400	16 Sept.	2000	10	NW	.3-1.8	NW becoming E	7.5	6	1.3	W	- movement with alongshore current; wind & sea direction - trajectory classified as very likely
	POSITION 4 to 5	16 Sept.	2000	17 Sept.	0900	5-10	NW becoming E to SE	.4 - 1.8	E/ ENE	13.9	13	1.1	W	- movement with mean alongshore current & wind direction - spill would have to increase substantially in size - trajectory classified as possible
	POSITION 5 to 6	17 Sept.	0900	17 Sept.	1900	10-15	SE	1.2	SE	12.6	10	1.3	W	- movement with mean alongshore current & wind direction - wind the spill would have to decrease substantially in size - possible trajectory
	POSITION 4 to 6	16 Sept.	2000	17 Sept.	1300	10-15	NW becoming SE	.4 - 1.8	E becoming SE	11.1	17	.7	NW	- movement with wind & sea direction - the possible trajectory

Table 4.2. Concluded.

OIL SPILL	TEST TRAJECTORIES	OBSERVATION$_1$		OBSERVATION$_2$		WIND BETWEEN OBSERVATIONS		SEA STATE BETWEEN OBS.		DIST. MOVED (KM)	TIME ELASPED (HR)	VELOCITY (KM/HR)	DIR OF DRIFT	REMARKS
		DATE	APPROX. TIME	DATE	APPROX. TIME	SPEED (KM)	DIR (FROM)	HT (m)	DIR (FROM)					
	POSITION 6 to 8	17 Sept.	1300	17 Sept.	1900	10-15	SE	1.0 - 1.2	SE	18.7	6	3.1	SW	- velocity high - movement with mean alongshore current - trajectory unlikely
16	5 to 6	17 Sept.	0900	17 Sept.	1300	8-15	SE	1.0 - 1.2	E/ SE	8.7	4	2.2	NE	- movement against alongshore current event with wind & sea direction - velocity high - trajectory classified as unlikely
OIL SEPT 17 SPILL	Spill location to T & C (1300)	17 Sept.	1100	17 Sept.	1300	8-15	SE	1.0 - 1.2	E/ SE	1.8	2	.9	W	- movement with alongshore current, wind & sea - trajectory classified as very likely
	T & C (1300) to Position 7	17 Sept.	1300	17 Sept.	1900	15	SE	1.0 - 1.2	SE	3.8	6	.6	W	- movement with alongshore currents, wind and sea - trajectory classified as very likely

Several characteristics of the spill noted at positon #2 suggested that this spill is the result of a tanker cleaning its bilge.

- shape: long (11.0 km) and narrow
- location: entrance to Halifax harbor
- timing: this spill was not identified during the morning flight but was observed after dark (2200 hours). This may suggest that tankers are using the cover of darkness to wash their bilges and escape detection by the Coast Guard. The trajectory evaluation indicates that the spill found at postion #3 at 0900 14 September could be related to the spill previously noted at position #2. The drift velocity of this movement would be 1 km/hr.

4.2.2 Oil Spill September 16 1983

The trajectory evaluation assumed that the test and control spills were dumped at approximately 1100 hr 16 September 1983. Both were positively identified at 1400 hr 16 September 3.9 km SW of the proposed spill location. This drift of 1.3 km/hr was with the "mean" alongshore current and at right angles to the prevailing wind direction. The trajectory evaluation indicates that the spill at position #4 (2000 hrs) is very likely related to the test and control spills. This indicates that the two spills have merged (within the elasped 9 hours) and the overall size of the spill has increased (see APPENDIX E for spill dispersion versus time).

The trajectory after 2000 hrs includes many possibilities and is likely complicated by the addition of other spills. While the location of Halifax has many logistical conveniences for an oil spill experiment like the 1983 Sea Trails, many spills of "indeterminate" origin can complicate the calculation of trajectories, drift rates etc. The most likely trajectory for the spill at position #4 would have it moving W or SW with the alongshore current and winds that prevailed over this period. Three spill locations were detected and mapped west of the 2000 hours observation of the test and control spills of September 16.

4.2.3 Oil Spill 17 September

For the trajectory evaluation it was assumed that the original test and control spills occurred at 1100 hrs at 44°30'N and 63°00'W. Both the test and control were positively identified at 1300 hours on 17 September, 1.8 km west of the spill site. This movement represents a drift rate of .9 km/hr in a direction coinciding with the alongshore current and prevailing wind direction.

By 1900 hours 17 September the spills had merged, increased in size and moved to a location (location #7 on Figure 4.3) 3.8 km west of the spill site. This motion coincides with the "mean" alongshore drift and prevailing wind direction over the period between 1300 hours and 1900 hours. The drift rate measured is .6 km/hr.

4.2.4 SLAR Flights 18 September

On September 18th two flights were conducted and the entire area of interest was surveyed both with radar and visually. Although no oil was found in the offshore areas a medium sized slick was observed on the beach and in the water in the Jeddore Cape area.

5. CONCLUSIONS

5.1 EVALUATION OF LIGHT WEIGHT DIGITAL SLAR FOR DETECTION AND MAPPING OF OIL SPILLS

5.1.1 During the 7 days over which aerial surveillance was conducted 15 oil spills were detected and mapped. Spills as small as 2.5 m^3 were observed on a regular basis. In this period wind speeds ranged from 5 to 15 knots with corresponding sea states of .4 to 1.8 m. Sea state direction generally correlated to surface wind direction. Surface winds of 5-15 knots are not expected to be a dominant force in surface water motion.

5.1.2 In total 12 flights were flown; accumulating approximately 20 flight hours. Average flight time was 1.7 hours; the average area surveyed was 16000 km^2. No delays due to weather or mechanical problems were encountered.

5.1.3 In this program one flight was conducted in direct support of each oil spill. Five daylight search flights were conducted to provide overall surveillance of the target area. To demonstrate the utility of radar reconnaissance in various low light conditions four night flights were undertaken. Of interest, many of the oil spills of "indeterminate" origin that were detected appear to occur after darkness. This suggests that considerable tanker bilge cleaning is occurring at the entrance to Halifax tanker; after darkness to prevent detection by the Coast Guard.

5.1.4 The radar and mission planning parameters that provided the most consistent oil spill detection included:

- operation at altitude of 3000-5000 ft:
- planning flight lines orthogonal to the surface wind direction. This approach maximized the background sea clutter in the upwind look direction; improving the contrast between the oil and uncontaminated ocean.
- increasing the gain of the radar until saturation began to occur in the near range.

5.1.5 The "mean" alongshore drift observed in this area in September (SW current) is most likely the result of the fresh water outflow from the St. Lawrence River. The peak of this outflow occurs in May or June with a resulting peak surface flow in the Halifax area in September. This southwest flow can be affected by high winds (> 15 knots) and tidal currents. Low wind speed over the course of these trials and general drift observations to the west and southwest suggest that this "mean" current is a major force in surface water movement in the Halifax area at this time of the year.

5.1.6 On all three "spill" days both test and control slicks were positively identified on the first flight immediately following each spill. Generally the test spill was shown to be larger (as it was laid down first and had dispersant applied to it). In general both the test and control spills were orientated with the prevailing wind direction. Landfall, the Edward Cornwallis, the Shoreham, the sampling vessels, fishing buoys and transient vessels can be observed in the radar imagery. The real time evaluation of such features from a radar image provides much of the critical information required in the tactical support of an actual oil spill cleanup or monitoring operation.

5.1.7 The location of each spill identified was calculated utilizing a computer program. Each position was plotted on a map to provide on overview of oil spill trajectory. In general the oil was seen to more to the west and southwest; suggesting a "mean" alongshore current in this direction. Drift velocities of .6 to 1.3 km/hr were observed.

5.1.8 The direction of motion of an oil spill appears to be one of the prime criteria in the decision of whether to combat the oil spill or not. If the motion is toward the coastline or on environmentally sensitive area a decision to combat the spill maybe required. If the movement is offshore a decision not to combat the spill may be more cost efficient. The real time, all weather information available from the radar can provide a reliable cost effective data source from which to make these decisions.

5.1.9 Rain can act as a natural dispersant. The rain imaged by the radar on the morning of September 13 maybe the reason why the spills of Sepember 12 could not be identified.

5.1.10 The size and shape, (long and narrow) location (entrance to Halifax Harbor) and timing (occuring after darkness) of many spills of "indeterminate" origin are suggestive of tanker bilge cleaning. An interesting experiment would be to overfly the Halifax harbor area over a period of several days to determine the number and size of oil spills occurring on a regular basis in the approach to one of Canada's busest harbors.

5.1.11 The test and control spills of September 16 and 17 were shown to merge within 8-9 hour after the oil was spilt.

5.1.12 During this program several spills of "indeterminate origin" were detected. These spills make the evaluation of the test spill trajectories very difficult. In future experiments increasing the frequency of flights and if possible selecting an area distant to frequently travelled tanker routes will provide more consistent and quantative oil spill trajectory information.

5.2 FURTHER EVALUATION OF OIL SPILL DATA SET

During the detailed planning of this project is was felt that the number of flight hours should be increased from those specified in the contract and that the additional funds required should be provided from the data analysis and reporting aspects of the program. In discussion with Environmental Protection Service representatives it was agreed that the funds remaining for the reporting aspects of the program would only allow for the annotation of the data, a brief description of the radar system and a preliminary evaluation of the oil spill data.

The nature of this data set (15 oil spills imaged in conjunction with a closely monitored and accurately reported experiment) lends itself to further detailed evaluation:

1. model performance of the SLAR in detecting oil spills under various environmental conditions leading to a definition of the utility and limitations of SLAR for oil slick detection and mapping. Variables to be included in this evaluation could include:

   - look direction (upwind versus downwind);
   - wind speed and direction;
   - wave height and direction;
   - oil thickness and distribution;
   - oil type and dispersant application;
   - radar range, altitude, depression angle and gain.

2. comparison of predicted trajectory (from oil spill models) and actual trajectory.

The detection of several oil slicks of indeterminate origin in the Halifax Harbor area suggests that tankers are cleaning their bilges during arrival or departure to Halifax. Most bilge cleaning incidents appear to occur at night when the operators can avoid detection by the Canadian Coast Guard. The availability of the INTERA SLAR aircraft in the Halifax area this March would be an excellent opportunity to confirm this hypothesis. The real time evaluation possible with this system would provide the Coast Guard with the information on a polluting vessel that may allow them to board the vessel (utilizing a fast launch positioned in the Harbor area) and collect the necessary water samples required as evidence in prosecuting an offender.

This demonstation would be undertaken to illustrate how airborne radar could provide real time information to the Coast Guard: helping to protect one of Canada's busiest harbor areas. The importance of this type of project becomes apparent if one considers that over a period of approximatey one week "several" (minimum 3-4) spills were detected which are unlikely related to the oil spill trails. Over 52 weeks approximately 150-200 spills may be contaniming the water and beaches of this area.

APPENDIX B

WIND SPEED AND DIRECTION AND SEA STATE.

EDWARD CORNWALLIS SEA STATE
DATA
OIL SPILL TRIALS SEPT 1983

SEPT 12/83 TIME (GMT)	HT.(M)	DIR(FROM)	PERIOD(SEC)
0015	2.0m	SW	
0221	1.5m	SW	
0400	1.8m	SW	5.0
0615	1.8m	SW	4.0
0802	1.5m	SW	5.0
1938	0.4m	SW	4.0
2117	0.4m	SW	4.0
SEPT 13/83			
0045	0.8m	250°	1.5
0500	0.6m	170°	2.3
0700	0.4m	210°	
SEPT 14/83			
0100	0.3m	EAST	5.0
0310	0.4m	NE	4.0
0930	0.8m	NE	3.8
1355	0.8m	NE	3.4
SEPT 16/83			
0105	0.3m	N	2.5
0300	0.4m	N	3.4
0755	0.3m	NW	3.5
1015	0.4m	N	3.0
1445	0.3m	NW	2.5
1750	1.1m	Nchop E-SE swell	5.0
2120	1.8m	E	7.5
SEPT 17/83			
0015	1.8m	E swell, N chop	6.0
0200	0.6m	ENE	6.8
0415	1.2m	ENE	7.5
0500	0.6m	N	4.1
0550	1.0m	E	2.5
0800	0.4m	E	7.5 (swell & chop)
1100	1.2m	E	7.0
1415	1.0m	SE	5.3
1600	1.2m	SE	6.2
1800	1.2m	SE	3.7

1983 OILSPILL TRIALS

EDWARD CORNWALLIS OBSERVED WEATHER

Date	Time (GMT)	Wind Speed(knots)	Direction(°T)
12 September 1983	0010	23	223
"	0115	19	219
"	0157	17	227
"	0240	18	235
"	0350	15	231
"	0555	15	250
"	0634	13	267
"	0739	9	253
"	0804	8	269
"	1933	14	223
"	2111	4	259
13 September 1983	0000	12-14	270
"	0500	light/variable	-
"	0800	5	240
"	1200	0.5	290
14 September 1983	0110	10	45
"	0205	15	50
"	0312	18	36
"	0358	17	35
"	0610	16	28
"	0930	15	20
"	1000	18	27
"	1030	18	27
"	1100	17	25
"	1200	15	22
"	1355	15	22

1983 OILSPILL TRIALS

EDWARD CORNWALLIS OBSERVED WEATHER

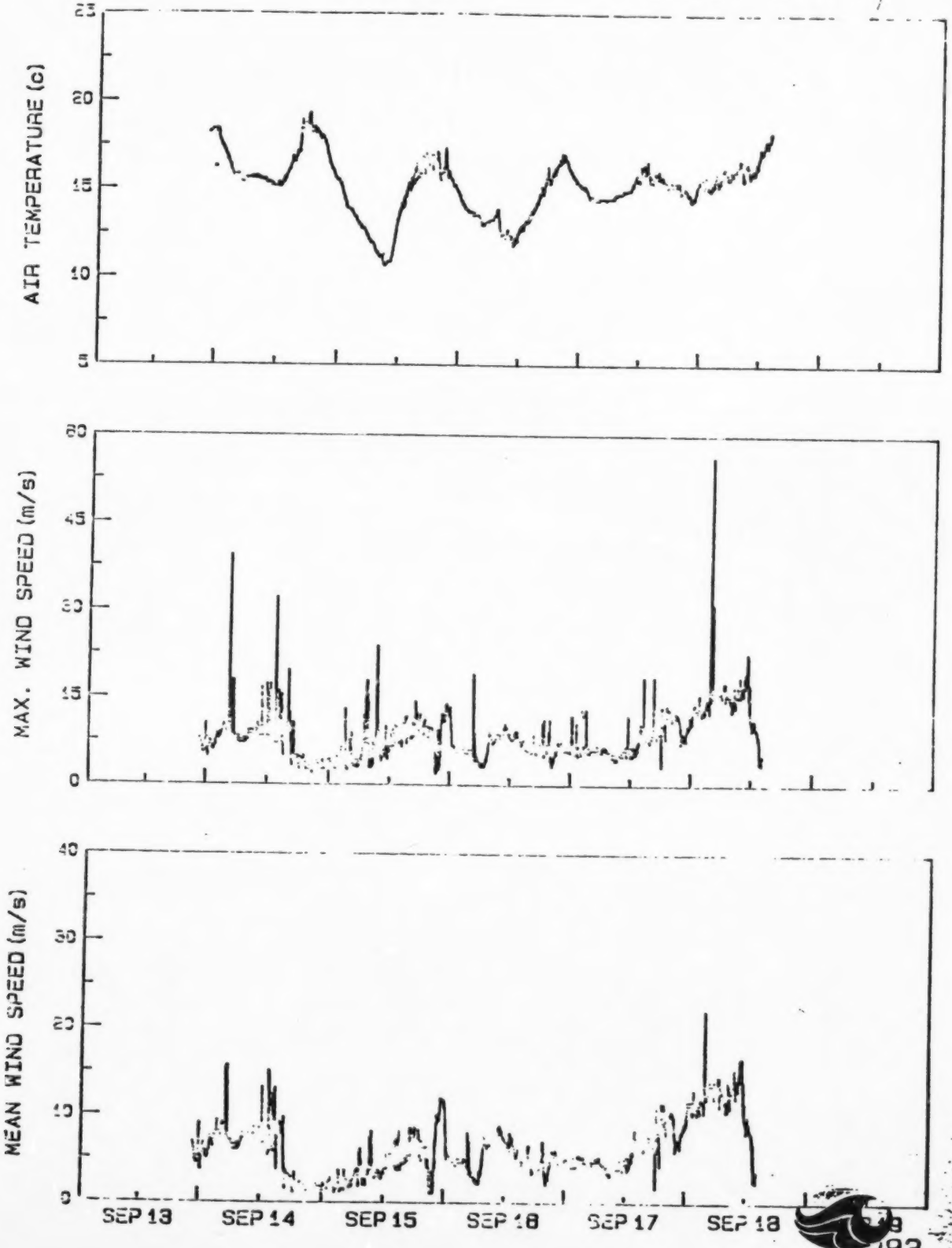
Date	Time (GMT)	Wind Speed(knots)	Direction(°T)
16 September 1983	0102	13	356
"	0300	12	342
"	0400	11	330
"	0753	15	310
"	1015	17	328
"	1445	9	303
"	1600	8	110
"	1750	12	250
"	1950	12	300
"	2125	10	313
17 September 1983	0015	13	18
"	0200	9	85
"	0415	12	85
"	0500	5	300
"	0530	C-3	300
"	0550	10	97
"	0800	10	105
"	1100	8	120
"	1415	15	130
"	1600	13	135
"	1800	15	140

STATION 188 WAVES RECORDED OFF C G S EDWARD CORNWALLIS PAGE 1

ROOT MEAN SQUARE WAVE HEIGHT (METRES) TABULATED BY WAVE PERIOD

RECORD -SIDE -TAPE	SEP HOUR	1983 -DAY	2.0 TO 3.0 SEC	3.0 TO 4.0 SEC	4.0 TO 5.0 SEC	5.0 TO 6.0 SEC	6.0 TO 7.0 SEC	7.0 TO 8.0 SEC	8.0 TO 9.0 SEC	9.0 TO 10.0 SEC	10.0 TO 11.0 SEC	11.0 TO 12.0 SEC	12.0 TO 13.0 SEC	13.0 TO 14.0 SEC	14.0 TO 15.0 SEC	15.0 TO 16.0 SEC	16.0 TO 20.0 SEC	CHAR WAVE HT IN M	PEAK PER. SEC.
1-1-1	1800	11	.10	.15	.18	.22	.12	.08	.04	.03	.02	.02	.02	.02	.02	.02	.01	1.50	5.25
2-1-1	2100	11	.10	.13	.20	.23	.11	.07	.04	.03	.02	.02	.02	.01	.01	.01	.01	1.51	5.46
3-1-1	0	12	.09	.11	.14	.17	.12	.08	.05	.03	.02	.02	.02	.02	.02	.01	.01	1.25	5.46
4-1-1	300	12	.07	.09	.11	.17	.12	.08	.05	.03	.02	.02	.02	.02	.01	.01	.01	1.13	5.46
5-1-1	600	12	.05	.08	.11	.16	.10	.08	.03	.03	.02	.02	.02	.03	.02	.01	.01	1.04	5.69
6-1-1	900	12	.05	.07	.11	.13	.14	.06	.04	.02	.02	.02	.02	.02	.02	.01	.01	1.00	6.50
7-1-1	1200	12	.04	.06	.10	.14	.08	.06	.04	.02	.02	.01	.02	.02	.02	.02	.01	.88	5.46
8-1-1	1500	12	.04	.06	.08	.12	.07	.05	.03	.02	.02	.02	.02	.02	.02	.01	.01	.78	5.25
9-1-1	1800	12	.07	.09	.09	.09	.05	.05	.03	.02	.02	.02	.02	.02	.01	.01	.01	.78	5.46
1-1-2	2100	12	.06	.08	.07	.08	.06	.05	.03	.02	.02	.02	.02	.02	.02	.01	.01	.69	5.04
2-1-2	0	13	.04	.05	.06	.08	.06	.04	.03	.02	.02	.03	.03	.02	.01	.01	.01	.61	5.46
3-1-2	300	13	.03	.05	.07	.06	.06	.05	.03	.03	.02	.03	.02	.02	.02	.01	.01	.59	6.83
4-1-2	600	13	.03	.04	.07	.07	.07	.04	.03	.02	.02	.03	.02	.02	.02	.01	.01	.60	6.83
5-1-2	900	13	.03	.06	.06	.07	.05	.05	.03	.03	.03	.02	.03	.03	.02	.01	.01	.61	5.25
6-1-2	1200	13	.08	.04	.05	.05	.04	.06	.06	.04	.02	.02	.02	.01	.01	.01	.01	.71	4.53
7-1-2	600	14	.10	.08	.06	.06	.06	.04	.05	.05	.03	.02	.02	.02	.01	.01	.01	.75	9.10
8-1-2	900	14	.09	.10	.07	.06	.05	.05	.05	.03	.03	.02	.02	.02	.02	.01	.01	.79	8.03
9-1-2	1200	14	.09	.09	.09	.05	.05	.04	.04	.03	.02	.03	.02	.02	.01	.01	.01	.74	4.27
10-1-2	1500	14	.08	.07	.08	.06	.04	.05	.04	.04	.02	.02	.03	.02	.02	.01	.01	.70	5.25
11-1-2	2000	15	.08	.17	.12	.10	.04	.03	.03	.02	.02	.02	.01	.01	.01	.01	.01	1.01	3.79
12-1-2	2100	15	.06	.14	.10	.10	.04	.03	.03	.02	.02	.02	.02	.01	.01	.01	.01	.91	5.06
13-1-2	0	16	.07	.07	.06	.05	.03	.02	.03	.02	.02	.01	.02	.01	.01	.01	.01	.55	4.68
14-1-2	300	16	.05	.05	.05	.03	.03	.03	.03	.02	.02	.02	.01	.01	.01	.01	.01	.43	4.68
15-1-2	600	16	.09	.05	.03	.04	.03	.03	.03	.03	.02	.02	.01	.01	.01	.01	.01	.53	2.84
16-1-2	900	16	.08	.09	.03	.03	.03	.03	.03	.03	.04	.02	.03	.02	.01	.01	.01	.62	3.33
17-1-2	1200	16	.06	.07	.03	.04	.08	.09	.08	.07	.04	.03	.03	.02	.01	.01	.01	.81	8.03
18-1-2	1500	16	.06	.06	.03	.07	.10	.15	.20	.17	.07	.03	.03	.02	.01	.01	.01	1.38	8.53
19-1-2	1800	16	.06	.04	.04	.05	.08	.13	.20	.16	.09	.06	.02	.01	.01	.01	.01	1.32	8.53
20-1-2	2100	16	.07	.04	.03	.05	.08	.11	.18	.15	.09	.04	.03	.02	.01	.01	.01	1.20	8.53
21-1-2	0	17	.06	.02	.04	.05	.08	.10	.14	.14	.07	.05	.02	.01	.01	.01	.01	1.06	9.10
22-1-2	300	17	.06	.04	.04	.05	.07	.07	.10	.12	.07	.04	.03	.01	.01	.01	.01	.89	9.10
23-1-2	600	17	.05	.04	.04	.05	.07	.09	.08	.10	.09	.04	.02	.01	.01	.01	.01	.89	9.75
24-1-2	900	17	.04	.03	.03	.04	.05	.08	.08	.10	.07	.03	.02	.01	.01	.01	.01	.78	9.75
25-1-2	1200	17	.09	.08	.04	.05	.07	.10	.11	.09	.05	.03	.02	.01	.01	.01	.01	.96	8.53
26-1-2	1500	17	.09	.13	.13	.05	.08	.07	.09	.08	.05	.03	.02	.01	.01	.01	.01	1.10	9.10
27-1-2	1800	17	.09	.10	.14	.10	.07	.07	.07	.06	.04	.02	.02	.01	.01	.00	.01	1.03	4.68
MONTHLY OR PARTIAL MONTHLY AVERAGES			.07	.08	.08	.08	.07	.06	.06	.05	.04	.03	.02	.02	.01	.01	.01	.89	6.52

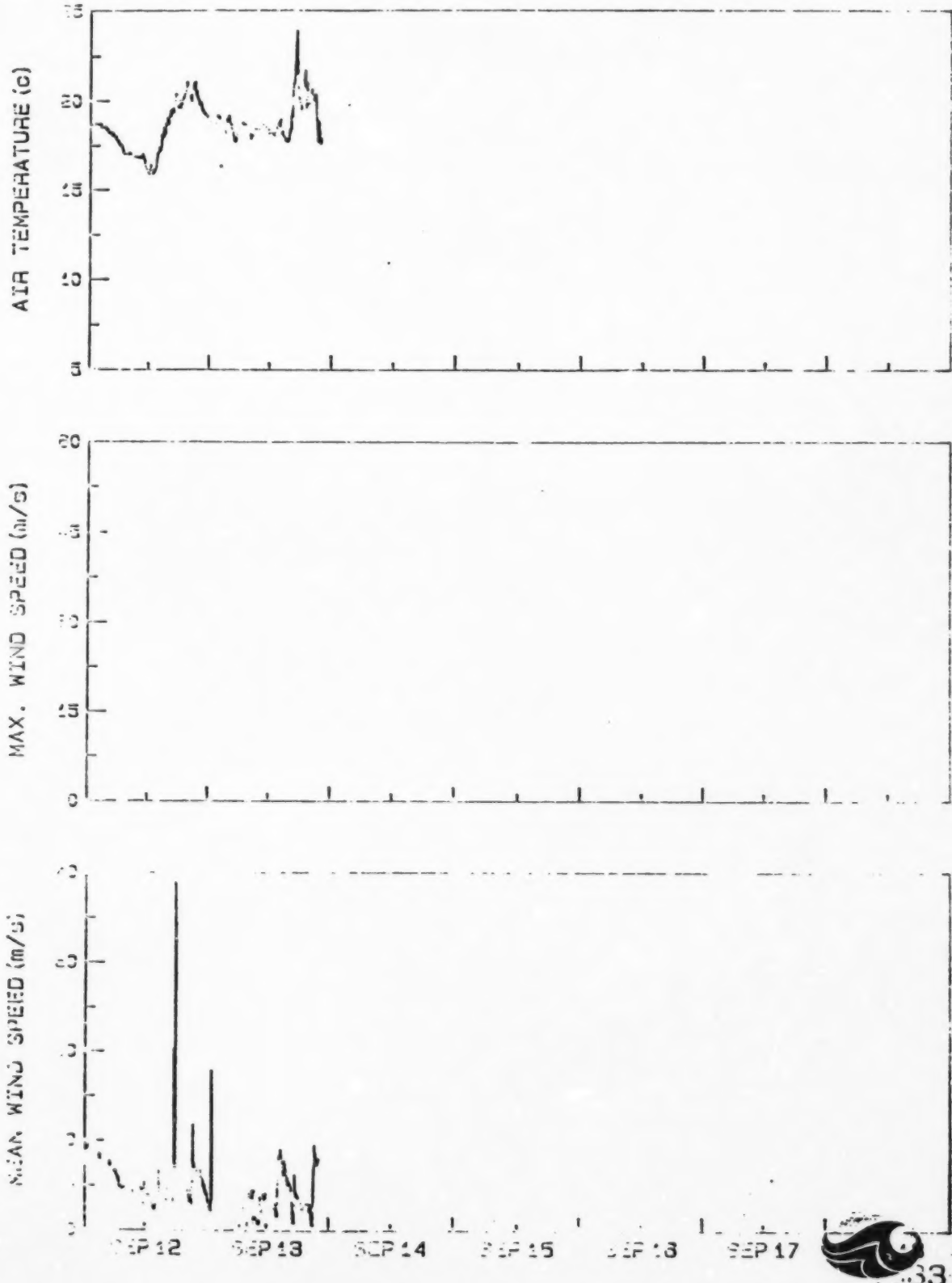
TIME SERIES OF MEAN & MAX. WIND SPEED & AIR TEMP.
COOSRA METER: 382/14
44°30'N 63°00'W AANDERAA DT (min): 5



TIME SERIES OF MEAN & MAX. WIND SPEED & AIR TEMP.

OOOSRA METER: 332/13

44° 30'N 63° 00'W AANDERAA DT (min): 5



APPENDIX C

CCT & VCR TAPE INDEXES

CCT DATA

OIL SPILL - HALIFAX 1983

Date	On	Off	Attitude	Look	SWW	Tape#	Line
Sept 10	13:40	15:45	27	B	100	1A	Calgary-Quebec City
Sept 11	16:42	18:51	10	B	50	1	LINE 1,2,3,4,5
Sept 12	14:45	16:39	10	B	50	2	LINE 1,2,3,4,5,6
Sept 13	8:02	9:12	5	B	50	3	LINE 1,2,3,4,5,6
Sept 13	20:33	21:59	3	B	50	4	LINE 1,2,3,4,5,6
Sept 14	7:52	9:15	3-5	B	50	5	LINE 1,2,3,4,5,6
Sept 14	20:14	21:39	5	B	50	6	LINE 1,2,3,4,5,6
Sept 16	12:42	13:46	5	B	50	7	LINE 1,2,3,4
Sept 16	19:19	20:00	5	B	50	8	LINE 1,2,3,4
Sept 17	08:10	09:10	5	B	50	9	LINE 1,2,3,4,5,6
Sept 17	12:25	13:32	5	B	50	10	LINE 1,2,3,4,5,6,7
Sept 17	18:45	19:21	5	B	50	11	LINE 1,2,3,4
Sept 18	11:55	13:05	5	B	50	12	LINE 1,2,3,4,5
Sept 18	13:54	14:42	5	B	50	13	LINE 1,2,3

1/2" VCR DATA OIL SPILL TRIALS
SEPTEMBER 1983

TAPE #	DATE	TIME (T.O.)	LINE	ALT (000's FT)	RD (usec)	SW (KM)	ANT	GS
2	12 SEPT	1445	1-6	10	40	50	B	200
7	13 SEPT	2030	1-6	3	12	50	B	180
8	14 SEPT	0800		5	20	50	B	180
9	14 SEPT	2000	1-4	5	20	50	B	180
11	16 SEPT			5	20	50	B	190
14	17 SEPT	1200		5	20	50	B	190
15	17 SEPT	1800		5	20	50	B	180
16	18 SEPT	1200		5	20	50	B	180
17	18 SEPT	1330		5	20	50	B	180

3/4" VCR DATA OIL SPILL TRIALS
SEPTEMBER 1983

TAPE #	DATE	TIME (T.O.)	LINE	ALT (000's FT)	RD (usec)	SW (KM)	ANT	GS
3	12 SEPT	1445	1-2	10	40	50	B	200
4	12 SEPT	1445	2-4	10	40	50	B	200
6	12 SEPT	1445	6	10	40	50	B	200
7	13 SEPT	0800		5	20	50	B	185
8	13 SEPT	0800		5	20	50	B	185
9	13 SEPT	2030	1-2	3	12	50	B	180
10	13 SEPT	2030	3-4-5	3	12	50	B	180
11	13 SEPT	2030	5-6	3	12	50	B	180
13	15-16-17 SEPT			5	20	50	B	180
14	17 SEPT	1200/1800		5	20	50	B	180

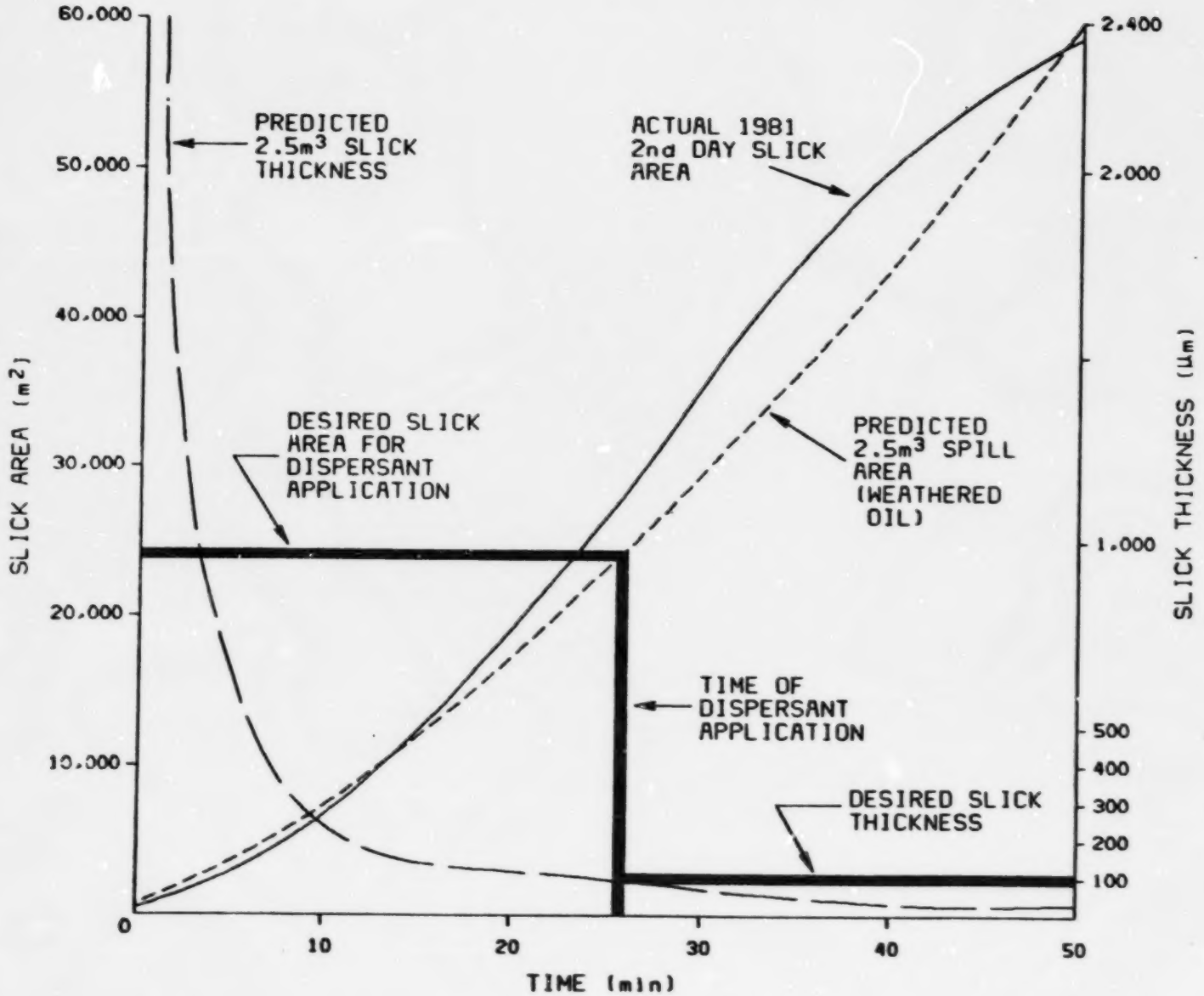
APPENDIX D

CALCULATION OF OIL SPILL POSITION

APPENDIX E

OIL SPILL DISPERSION VERSUS TIME

SLICK SPREADING



POOR

QUALITY

ORIGINAL